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PROSPECTS FOR PION AND KAON FACTORIES

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"PION FACTORY" is commonly understood to mean an accelerator which produces a proton beam of at least 100 μA average current, at an energy above 400 MeV. Three facilities, namely LAMPF, SIN, and TRIUMF are in operation, and a fourth is being constructed near Moscow. These beam intensities are several orders of magnitude more than for the synchrocyclotrons which they replaced. The secondary beams of pions produced are certainly of primary interest, but also important have been the beams of protons and neutrons, muons, and fluxes of neutrinos available.

A number of specialized beams have grown up around these facilities. They include chopped proton and neutron beams, surface muon beams, polarized proton and neutron beams, etc. The LAMPF beam stop is a source of electron neutrinos with a flux of $\sim 5 \times 10^7 \nu_e/\text{s-cm}^2$ at a distance of 8 meters and a primary proton current of 1 mA. (Actual proton beams at the dump are presently about 400 μA.) High resolution spectrometers for p-nucleus reactions, for π-single and double charge exchange reactions, for pionic and muonic atomic are in use. Large detectors for rare decay searches, for neutrino studies, etc., have been built and operated.

That the discipline of medium-energy science is thriving as a result of all these activities is documented by the many recent conferences on high-energy physics and nuclear structure, specialized conferences, and monographs.[1]

LAMPF Improvements

The major addition planned for the near-term at LAMPF is a proton storage ring for 800-MeV protons, which will be used in either a long bunch mode to produce thermal neutrons, or in a short bunch mode to produce intense short bursts of neutrons for nuclear physics.[2] This will be a powerful extension of the capabilities of the existing neutron time-of-flight area. The potential uses of the neutrino fluxes from the storage ring facility are of great interest.[3]

TRIUMF Improvements

Design and development activities are going on aiming at eventual replacement of the central resonators for the cyclotron. The goal is to improve the mechanical stability of the resonators and the ability to handle them remotely. This will facilitate higher intensity operation of the machine.

Recently a new fast pion channel, the so-called M11 channel, was installed. It is a zero degree, high resolution pion source. An rf separator has been put on the M9 channel for use with the cloud muon beam. A beam line for 70- to 100-MeV protons is being designed for isotope production.

SIN Improvements

The most notable change at SIN will be the commissioning of the new injector cyclotron which is now being readied. This will allow the old injector to run in a dedicated mode for low-energy nuclear physics, and allow the new one to be a dedicated injector. The new injector holds promise of greatly increased currents, perhaps as much as several milliamperes at 550 MeV. In order to exploit such currents, new secondary beam lines, new targets, and new beam dumps would be required. Use of a dump as a spallation source of neutrons, especially cold neutrons, is being considered. The new pion channel for biomedical studies is just coming into operation.

Kaon Factories

This term, rather a misnomer, is used for proton machines in the energy region 8 to 30 GeV, which are to offer orders of magnitude improvement in average current over existing facilities in this energy interval.

At Los Alamos, a fast cycling synchrotron injected with H^- from LAMPF has been discussed repeatedly.[4] The Fermilab booster synchrotron has been proposed as a kaon factory.[5] Table I lists some synchrotron parameters given in a recent talk by Teng.[6] The design is not very different from the booster at Fermilab, the principal differences being a doubling of the repetition rate from 15 to 30 Hz, changes in the injection and final energies, and concomitant changes in ring diameter and rf power requirements. The higher injection energy of LAMPF (800 vs. 200 at Fermilab) results in a reduced rf frequency swing (18% vs. 174%) and an improvement in the canonical injection space charge limit by a factor of 8.

TABLE I

Injection Energy	0.8 GeV
Final Energy	16.0 GeV
Average Current	100.0 μA
Repetition Rate	30.0 Hz
Magnet Bending Radius	81.5 m
Magnet Power	2.5 MW
Mean Radius of Ring	122 m
Lattice	24 cells DFOOFD
Tune (ν)	8-1/4
Protons/Pulse	2×10^{13}
Space Charge Limit	3.4×10^{13}
Injection Frequency	50.0 MHz
Final Frequency	59.6 MHz
Energy Gain/Turn	3.7 MeV (max)
Peak rf Voltage/Turn	4.3 MV
Cavity rf Loss	∿2 MW
Injector No. Turns	90 T (360 T) for 12-mA peak

Stretcher

To increase the duty factor of the synchrotron, the beam may be transferred to a dc ring having the same circumference and installed in the synchrotron tunnel. This ring could very well use superconducting magnets. H^- beam injection into the synchrotron would require a new, high-current, high-brightness H^- source. Such a source is now being developed for the proton storage ring by R. Stevens at Los Alamos, based on the work of Ehlers and Leung[7] at LBL. Another requirement for both the storage ring and for a synchrotron is to accelerate simultaneously with minimal losses beams of H^+ and H^- in the linac. Up to now the procedure has been to tune for best transmission of the H^+ beam and to accept some losses in the H^- beam. Obviously, beam loss in the synchrotron is also a much more serious problem for a kaon factory than for a booster.

At Vancouver, some of the TRIUMF staff have been studying accelerators which, using the present cyclotron as an injector, would produce beams of 8 to 20 GeV.[8] The CANUCK scheme envisages a 3-GeV ring cyclotron and an 8.5-GeV ring cyclotron in series, probably employing superconducting magnets. The current would be 400 μA. Another scheme would use a fast cycling synchrotron with a final energy of 20 GeV. Still another possibility being studied is a rapid cycling 3-GeV booster injecting into a slow cycling synchrotron with final energy 20 GeV. The final currents suggested are 200 μA, certainly an impressive number! R. Wilson independently suggested a superconducting synchrotron.[9]

All of these designs will have to deal with questions of beam loss and beam diagnostics and control very carefully indeed.

For all of these studies, there are also outstanding questions about the facility which react back on the design of the accelerator. Some of these questions are:

1) What should be the final energy? Whether to pursue antiproton physics, the matter of facility cost, the energy dependence of the production cross sections for kaons, antiprotons, etc., enter into this decision. More experiments on production cross sections would be very useful. If there are to be $\bar{p}$ beams, how many and what kind?

2) How may kinds of k beams and what kind should there be?

3) Should polarized proton beams be provided?

4) Are targeting systems to be serial-parallel as at LAMPF, or parallel as at most large proton synchrotrons?

5) How can one make much brighter and higher purity secondary and tertiary (e.g., K^0 beams?)

6) What high resolution facilities for nuclear physics should be provided?

Conclusion

In general, the pion factories have lived up to the expectations for them with respect to their performance as accelerators and their output of interesting results on the physics of particles and of the nucleus. Interest in "kaon factories," seen as an extension of the pion factories, is presently very high, both as to accelerator design and as to facility and experimental program planning.[10]

In 1975, R. R. Wilson called my attention to the Fermilab booster's capabilities. On the subject of fast-cycling synchrotrons, conversations with Lee Teng, R. R. Wilson, C. Owen, B. Brown, C. Hovjat, C. Schmidt, and Q. Kearns have been extremely helpful. Conversations with M. Craddock about the TRIUMF program have been very useful.

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